AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 111:185–191 (2000)

Population Variation in Osteological Aging Criteria: An Example From the Pubic Symphysis

ROBERT D. HOPPA*
Department of Anthropology, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

KEY WORDS age determination; palaeodemography; pubic symphysis; representativeness

ABSTRACT A fundamental assumption made by skeletal biologists is that both the pattern and rate of age-related morphological changes observed in modern reference populations are not significantly different than in past populations. In this brief exploration, the composition of a single reference and two independent, known-age, target samples are evaluated for the pubic symphysis. Differences in the timing of age-progressive changes between the reference and target samples are observed, and in particular, females demonstrated a pattern that was fundamentally different from the reference sample. These results serve as a cautionary note for the use of osteological aging criteria and issues of representativeness for modern standards. Am J Phys Anthropol 111:185–191, 2000.

Estimates of demographic parameters in past populations necessarily assume that the biological process related to mortality and fertility in humans was the same in the past as it is in the present (Howell, 1976; Weiss, 1973, 1975; see also Paine, 1997). However, not only the broader issues of demographic structure must conform to this assumption. Estimates of individual age from skeletal remains must also assume uniformitarianism in the use of biological aging criteria, such that the pattern of age progressive changes observed in modern reference populations is not significantly different from the pattern observed in past populations.

Lovejoy et al. (1995, 1997) noted that while great strides have been made in our ability to make simple demographic estimates from skeletal remains, previous studies were primarily typological, and future progress requires an improved understanding of the fundamental biology of human skeletal aging. As such, inherent variation in the biological process of aging in the skeleton is a fundamental source of error for present osteological aging criteria (Bocquet-Appel and Masset, 1982; Lovejoy et al., 1997). Bocquet-Appel and Masset (1982) argued that there is an inherent inaccuracy and unreliability of *all* age estimation techniques because of the low correlation between skeletal age and chronological age. Further, differences in age-related changes in the human skeleton may impede the use of such criteria on skeletal samples that differ significantly in time from the reference (Angel et al., 1986; Bocquet-Appel and Masset, 1982; Kemkes-Grottenthaler, 1996; Murray and Murray, 1991).

This issue is not unfamiliar to investigators, but its exploration has been greatest in the context of forensic anthropology, with the development and testing of population specific standards for various aging criteria (e.g., Bedford et al., 1993; Brooks and Suchey, 1990; Lovejoy et al., 1985; Lucy et al., 1995; Meindl et al., 1983, 1985). This question has been explored less fully with respect to past

*Correspondence to: Robert D. Hoppa, Department of Anthropology, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada. E-mail: hoppard@ms.umanitoba.ca

Received 17 March 1999; accepted 12 September 1999.

populations because of the relative scarcity of samples of known age distribution, and because differences between chronological and biological age may increase as we go back in time (Iscan and Loth, 1989). Nevertheless, when such samples are available, uniformity of age changes has been implicitly addressed by analyses of accuracy and bias for various aging criteria (e.g., Molleson et al., 1993; Saunders et al., 1992).

Most studies of accuracy for osteological aging criteria have observed differences between estimated and true age, but few offer explanations beyond the reference distribution being relatively older or younger than the target sample. This brief exploration is an attempt to quantify those differences to better understand the implications of population variability with respect to skeletal aging methods.

MATERIALS AND METHODS

The reference distribution for the Suchey-Brooks method (Suchey et al., 1988) of estimating age from the *symphysis pubis* was compared to two independent target samples for which the same technique was applied and true age was known. The first represents a 20th century forensic sample of similar composition to that of the reference sample (Klepinger et al., 1992). The second represents an archaeological sample derived from the 18th–19th century Spitalfields sample of known-age individuals (Molleson et al., 1993). Sample sizes are presented in Table 1. The distributions of age and age indicator stage were explored, and the observed distribution of the reference sample was compared to the two independent target samples.

TABLE 1. Frequency distribution of Suchey-Brooks stages for each known-age sample

		Source		
Sex	Stage	Suchey-Brooks	Klepinger	Spitalfields
Females	1	48	12	5
	2	47	9	4
	3	44	46	11
	4	39	62	20
	5	44	54	18
	6	51	46	10
Total		273	229	68
Males	1	121	11	3
	2	81	6	2
	3	43	15	6
	4	152	44	26
	5	240	24	17
	6	100	17	15
Total		737	117	69

RESULTS AND DISCUSSION

Figure 1 presents the age distribution of each sample (by sex) grouped by 10-year intervals. Overall, the reference distribution is significantly younger than in the two target samples ($P < 0.001$), but there were few significant differences in mean age within each 10-year cohort, with post hoc comparisons observing differences significant at $P < 0.05$ in two age intervals for females (40 and 60) and in one age interval (70) for males.

Figure 2 presents the distribution of age by phase for the Suchey-Brooks reference sample. Summary statistics support the supposition that subsequent phases have significantly higher mean ages ($F = 116.69$, $P < 0.001$ for females; $F = 306.593$, $P < 0.001$ for males), and that age is significantly correlated with phases (Spearman's rho = 0.862, $P < 0.001$ for males and Spearman's rho = 0.884, $P < 0.001$ for females).

These statistical relationships provide the basis for using this technique to estimate age-at-death in the skeleton. However, as illustrated in Figure 3, the mean phase of each 10-year group within the reference and two target samples is *not* the same. That is to say, the rate of changes in the three samples is significantly different. This is particularly true for females, who showed statistically significant differences after about 30 years of age. The males were not as divergent, and with a few exceptions probably related to sample size (see Table 2), the standard errors between each sample for the most part overlap.

It is not simply that the age-estimation method is too coarse to capture accurately the true demographic profile of the target samples. That is to say, underestimation of true age is not simply a product of having only six stage means with which to compare with true age. It is clear, for example, that simple error testing using mean age of assigned stage and true age will often result in underestimates. This type of error is evi-

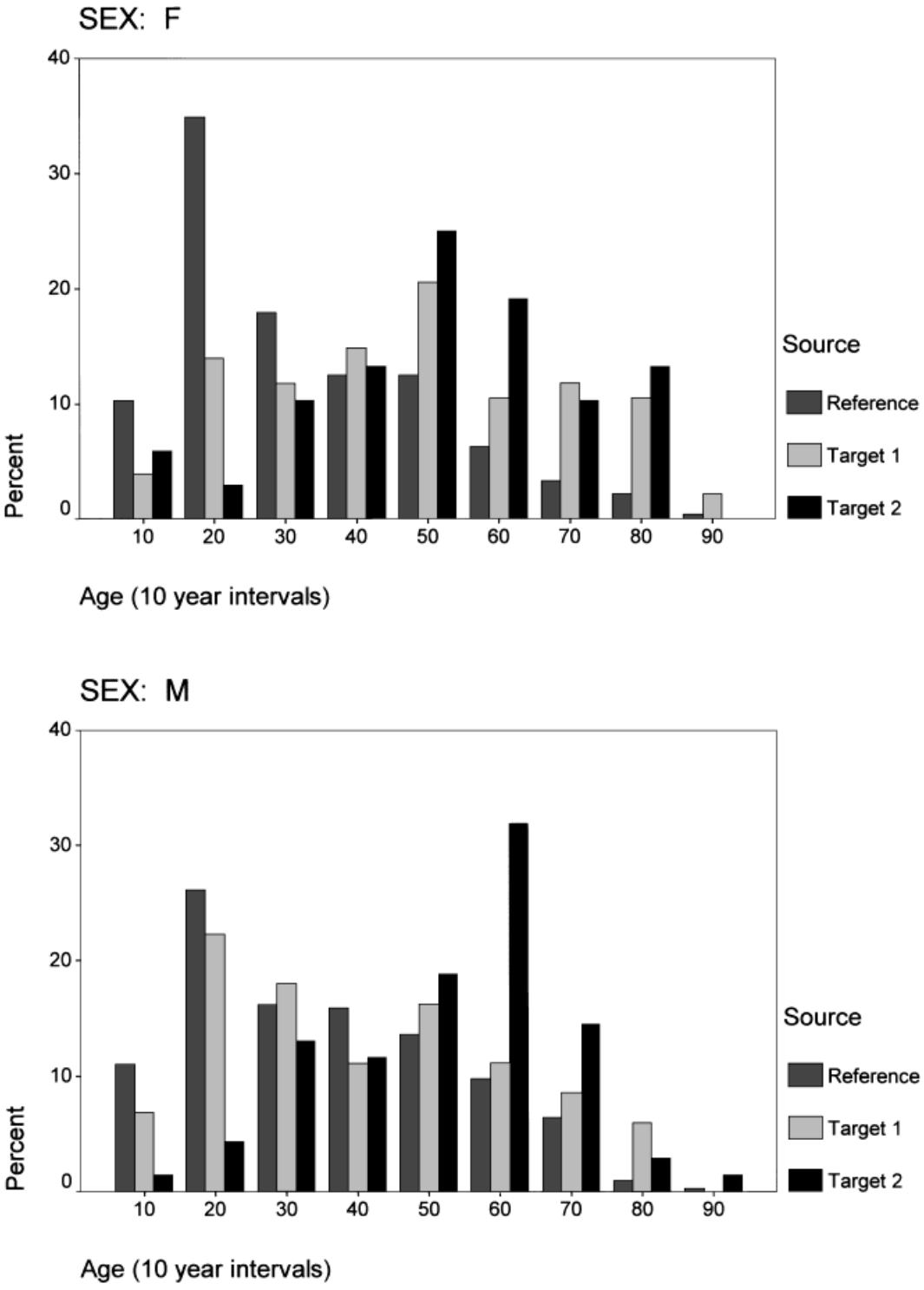

Fig. 1. Distribution by age, of the reference and two target samples.

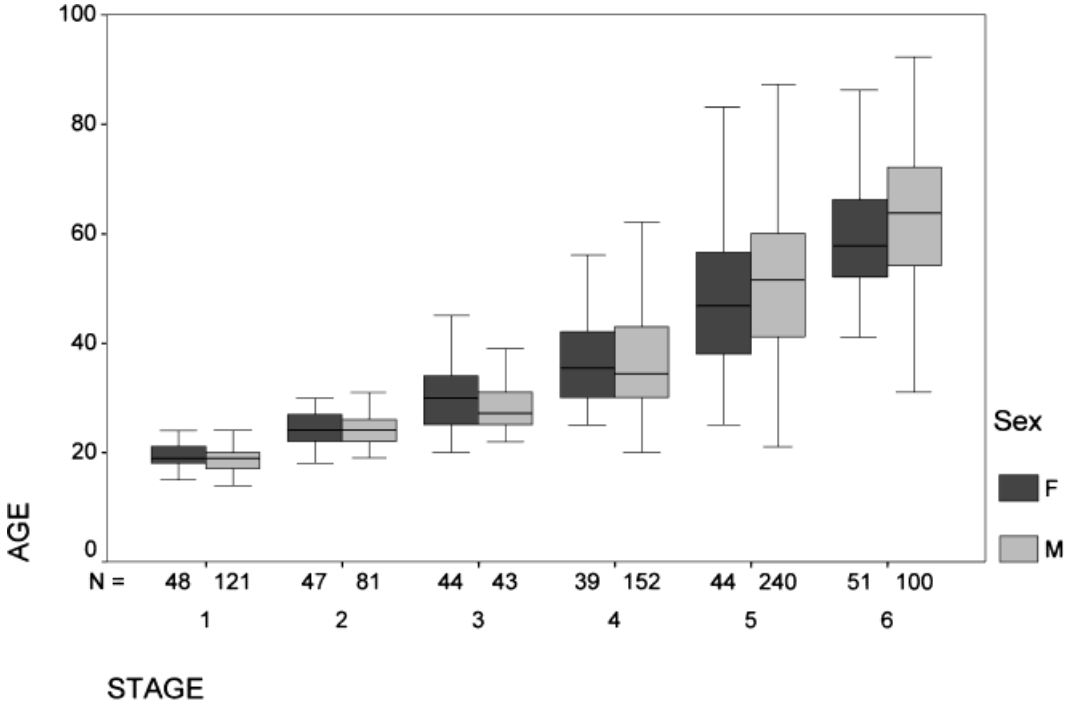

Fig. 2. Box plot showing distribution of age, within each indicator state for the reference sample.

denced in various studies of accuracy and bias for the pubic symphysis aging methods (e.g., Hanihara and Suzuki, 1978; Katz and Suchey, 1986; Klepinger et al., 1992; Todd, 1927). This conclusion is supported by the original researchers who noted that regression analysis of age on pubic symphyseal variables "performed poorly for 'older' groups" (Katz and Suchey, 1986, p. 433), and that the results improved dramatically with the removal of individuals over 40 years of age. Even the optimism of Todd (1927) at being able to age individuals skeletally ± 2 years of true age, was tempered by the axiom "that [age] be sixty years or less." However, here we see also that the rate of early development and later degeneration between the three relatively contemporaneous samples is different, and significantly so for females. As illustrated in Figure 3, forensic sample (target 1) females, from about 40 years on, have earlier morphological changes (i.e., are younger looking) than the reference sample at comparable ages. The archaeological sample (target 2) shows even younger-looking bones from about 30 years of age.

Other researchers have also noted population differences in the developmental morphology of the pubic symphysis. For example, Sinha and Gupta (1995) observed significant differences in the mean age of phases in their comparison of the method of Todd (1927) of pubic development in a sample of males from India, with phases II, III, and VI–X having significantly lower mean ages of development than in the reference sample of Todd (1927). Further comparison of the Indian sample using the component method of McKern and Strewart (1957) showed inconsistent differences in developmental timing, similar to those observed by Pal and Tamankar (1983).

> . . . the development of dorsal margin is earlier in Indian bones. However, the completion of the dorsal plateau is delayed. The completion of ventral beveling and rampart is delayed as against the formation of the symphyseal rim, which starts earlier, but completes later in Indian bones (Sinha and Gupta, 1995, p. 76).

Like this study, most others have also observed greater variability in female pubic morphology, often attributed to reproductive

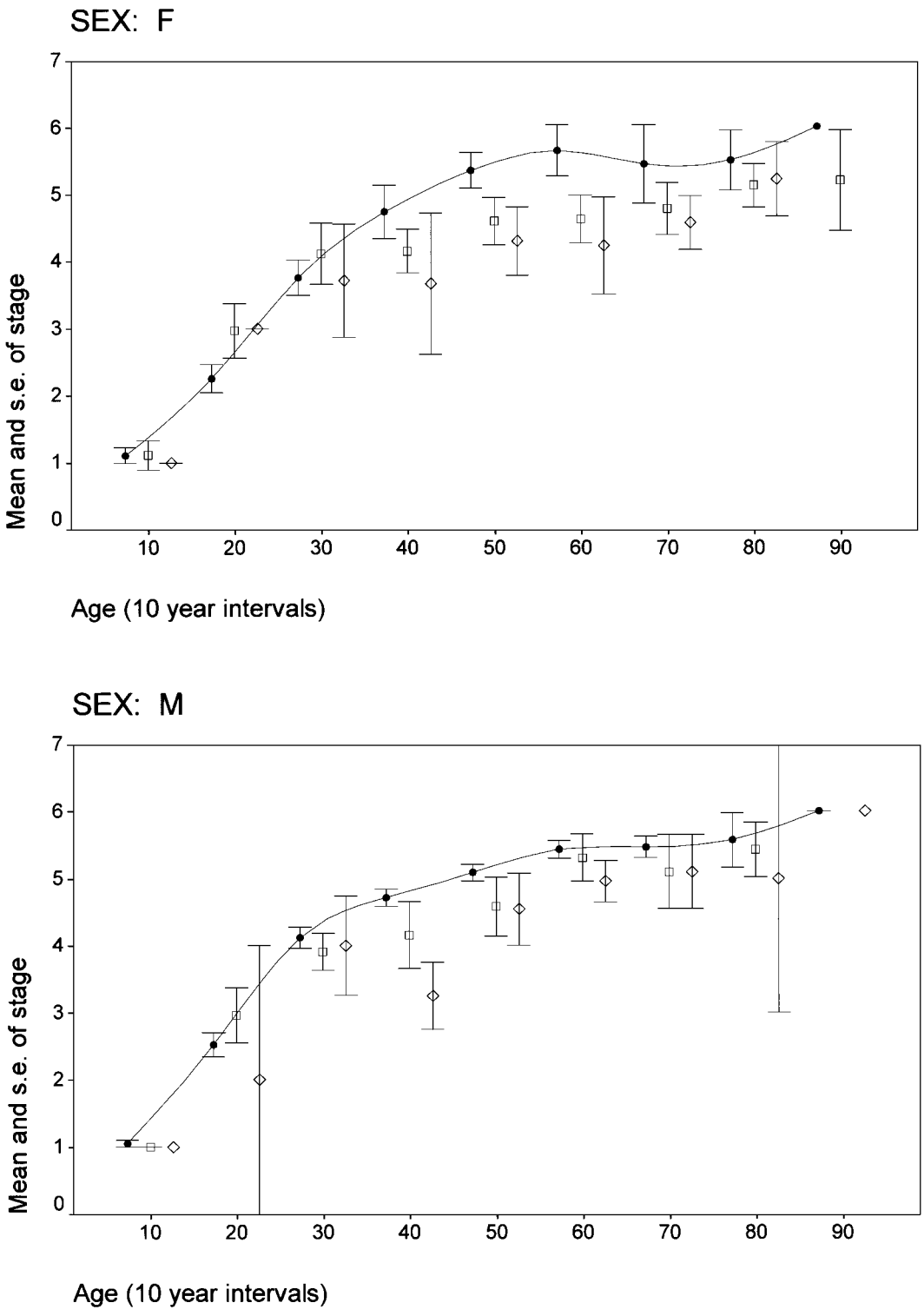

Fig. 3. Mean and two standard errors of stage by 10-year intervals for known-age males in females in the reference (solid circles) and two target samples (target 1, open squares; target 2, open diamonds).

TABLE 2. Frequency of individuals in each 10-year age interval in the reference and two target samples

Sex	Age group	Source			Total
		Suchey-Brooks	Klepinger	Spital-fields	
Females	10	28	9	4	41
	20	95	32	2	129
	30	49	27	7	83
	40	34	34	9	77
	50	34	47	17	98
	60	17	24	13	54
	70	9	27	7	43
	80	6	24	9	39
	90	1	5		6
Males	10	81	8	1	90
	20	192	26	3	221
	30	119	21	9	149
	40	117	13	8	138
	50	100	19	13	132
	60	72	13	22	107
	70	47	10	10	67
	80	7	7	2	16
	90	2		1	3

changes in hormonal levels and the trauma associated with childbearing (Bergfelder and Hermann, 1980; Putschar, 1976; Suchey et al., 1979; see also Tague, 1990). The data used here from the Spitalfields sample did have parity recorded, and ignoring any problems with the accuracy of such data, a very crude analysis demonstrated no significant differences in the variation of mean stage by age between low-birth vs. high-birth females, although the samples sizes were very small.

CONCLUSIONS

The results of this exploration suggest that differences in the timing of age-related changes for osteological criteria may be significant between reference and target samples. It must be emphasized that this critique is not an attack on the Suchey-Brooks method. After all, like the Suchey-Brooks technique, many other current techniques are modifications or revisions of Todd's original system proposed in the 1920s. Rather, it is meant as a cautionary note that can be illustrated because the original reference data for this method are readily available—a point not true of most other aging criteria that have been published. The results of this brief examination, it is hoped, will serve as a reminder that mapping the physiological process of aging on the bony skeleton is a difficult and challenging task. And while variation in the rate of development at the individual level may be small, the impact at the aggregate or population level is potentially great and certainly significant in terms of estimating the demographic parameters of the oldest old in osteological samples.

ACKNOWLEDGMENTS

I gratefully acknowledge Linda Klepinger for providing me with her original data. Sheilagh Brooks, Louise Humphrey, and Theya Molleson provided permission and access to the Suchey-Brooks database collected on the Spitalfields collection. For their helpful comments I thank Mary Jackes, James Vaupel, and Charles FitzGerald. This research was conducted while the author was a Research Scientist at the Max Planck Institute for Demographic Research (Rostock, Germany).

LITERATURE CITED

Angel JL, Suchey JM, Iscan MY, Zimmerman MR. 1986. Age at death from the skeleton and viscera. In: Zimmerman MR, Angel JL, editors. Dating and age determination in biological materials. London: Croom Helm. p 179–220.

Bedford ME, Russel KF, Lovejoy CO, Meindl RS, Simpson SW, Stuart-Macadam PL. 1993. Test of the multifactorial aging method using skeletons with known age-at-death from the Grant collection. Am J Phys Anthropol 91:287–297.

Bergfelder T, Hermann B. 1980. Estimating fertility on the basis of birth-traumatic changes in the pubic bone. J Hum Evol 9:611–613.

Bocquet-Appel J-P, Masset C. 1982. Farewell to palaeodemography. J Hum Evol 11:321–333.

Brooks ST, Suchey JM. 1990. Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. Hum Evol 5:227–238.

Hanihara K, Suzuki T. 1978. Estimation of age from the pubic symphysis by means of multiple regression analysis. Am J Phys Anthropol 48:233–240.

Howell N. 1976. Toward a uniformitarian theory of human palaeodemography. J Hum Evol 5:25–40.

Iscan MY, Loth SR. 1989. Osteological manifestations of age in the adult. In: Iscan MY, Kennedy KAR, editors. Reconstruction of life from the skeleton. New York: Alan R. Liss, Inc. p 23–40.

Katz D, Suchey JM. 1986. Age determination of the male os pubis. Am J Phys Anthropol 69:427–435.

Kemkes-Grottenthaler A. 1996. Critical evaluation of osteomophognostic methods to estimate adult age at death: a test of the "complex method". Homo 46:280–292.

Klepinger LL, Katz D, Micozzi MS, Carroll L. 1992. Evaluation of cast methods for estimating age from the *os pubis*. J Forensic Sci 37:763–770.

Lovejoy CO, Meindl RS, Mensforth RP, Barton TJ. 1985 Multifactorial determination of skeletal age at death: a method and blind tests of its accuracy. Am J Phys Anthropol 68:1–14.

Lovejoy CO, Meindl RS, Tague RG, Latimer BM. 1995. The senescent biology of the hominoid pelvis: its bearing on the pubic symphysis and auricular surfaces as age-at-death indicators is the human skeleton. Riv Antropol 73:31–49.

Lovejoy CO, Meindl RS, Tague RG, Latimer B. 1997. The comparative senescent biology of the hominoid pelvis and its implications for the use of age-at-death indicators in the human skeleton. In: Paine RR, editor. Integrating archaeological demography in multidisciplinary approaches to prehistoric populations. Occasional papers 24. Carbondale: Center for Archaeological Investigations, Southern Illinois University. p 43–63.

Lucy D, Pollard AM, Roberts CA. 1995. A comparison of three dental techniques for estimating age at death in humans. J Archaeol Sci 22:417–428.

McKern TW, Stewart TD. 1957. Skeletal age changes in young American males. U.S. Army Quartermaster Research and Development Command, Technical Report.

Meindl RS, Lovejoy CO, Mensforth RP. 1983. Skeletal age at death: accuracy of determination and implications for human demography. Hum Biol 55:73–87.

Meindl RS, Lovejoy CO, Mensforth RP, Walker RA. 1985. A revised method of age determination using the os pubis, with a review of tests of accuracy of other current methods of pubic symphyseal aging. Am J Phys Anthropol 68:29–45.

Molleson TI, Cox M, Waldron AH, Whittaker DK. 1993. The Spitalfields project. The middling sort. Volume 2—The anthropology. Council for British Archaeology Research Report 86.

Murray KA, Murray T. 1991. A test of the auricular surface aging technique. J Forensic Sci 36:1162–1169.

Paine RR. 1997. The role of uniformitarian models in osteological paleodemography. In: Paine RR, editor. Integrating archaeological demography in multidisciplinary approaches to prehistoric populations. Occasional papers 24. Carbondale: Center for Archaeological Investigations, Southern Illinois University. p 191–204.

Pal GP, Tamankar BP. 1983. Determination of age from the pubic symphysis. Indian J Med Res 99:694–701.

Putschar WG. 1976. The structure of the human symphysis pubis with special consideration of parturition and its sequelae. Am J Phys Anthropol 45:589–594.

Saunders SR, FitzGerald C, Rogers T, Dudar C, McKillop H. 1992. A test of several methods of skeletal age estimation using a documented archaeological sample. Can Soc Forensic Sci J 25:97–118.

Sinha A, Gupta V. 1995. A study on estimation of age from pubic symphysis. Forensic Sci Int 75:73–78.

Suchey JM, Wiseley DV, Green RF, Noguchi TT. 1979. Analysis of dorsal pitting in the os pubis in an extensive sample of modern American females. Am J Phys Anthropol 51:517–539.

Suchey JM, Brooks ST, Katz D. 1988. Instructions for use of the Suchey-Brooks system for age determination for the female os pubis. Instructional materials accompanying female pubic symphyseal models of the Suchey-Brooks system, distributed by France Casting (Diane France, 20102 Buckhorn Rd., Bellvue, CO 80512).

Tague RG. 1990. Morphology of the pubis and preauricular area in relations to parity and age at death in *Macaca mulatta*. Am J Phys Anthropol 82:517–525.

Todd TW. 1920. Age changes in the pubic bone. I. The male white pubis. Am J Phys Anthropol 3:285–334.

Todd TW. 1927. Skeletal records of mortality. Sci Monthly 1927:481–496.

Weiss KM. 1973. Demographic models for anthropology. Am Antiquity 38:(2), part 2. 186 p.

Weiss KM. 1975. Demographic disturbance and the use of life tables in anthropology. Am Antiquity 40:46–56.